

Evidences of Fold Superimposition from Anakapalle, Eastern Ghats Mobile Belt, India

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Abstract

The granulite facies terrain of the Eastern Ghats Mobile Belt (EGMB) is significantly important due to its complicated tectonic setting attained in response to polyphase deformation and related metamorphic episodes. Repeated deformation, upheaval and burial of rocks seem related to interaction of different crustal blocks characterized with collisional tectonics and extensive igneous activity during Archean Era. Polyphase deformed rocks display multidirectional tectonic trends and out of which NE-SW and NW-SE are the most prominent and represented in the form of macroscale superimposed plunging folds. The superimposed folds have given rise to linear ridges, residual hills and intermontane flat pediment surfaces imparting an overall uneven topography to the area. These two cross-cutting trends appear to have affected the whole of the EGMB and demand for proper chronological constraints to be related to specific intracontinental to Gondwanaland events.

Keywords

Fold Superimposition; Remote Sensing; Anakapalle; Eastern Ghats Mobile Belt

Introduction

The area investigated for structural deformation using field and remote sensing data around Anakapalle (Latitude 17° 39' 10" N to 17° 45' 00" N and Longitude 83° 00' 00" E to 83° 07' 00" E) constitute a part of the granulite facies terrain of the Eastern Ghats Mobile Belt (EGMB) (Fig.1a,b). EGMB is separated from the Eastern Dharwar and Bastar cratons in west by eastward dipping NNE-SSW trending thrust confirmed by deep seismic studies^[1]. The Sukinda thrust separates the high-grade rocks of the Eastern Ghats Belt in the south from Singhbhum-Orissa Craton in the north.

Precambrian rocks of the mobile belt display prograde metamorphism from greenschist and amphibolite facies developed towards the west of Nellore to granulite facies exposed towards the north-eastern

part of EGMB. Granulite facies assemblage of the EGMB composed of khondalites and leptynites, charnockites and enderbites, basic granulites, calc-granulites, quartz-bearing and quartz-free types of sapphirine-bearing granulites is included in the Eastern Ghats Group, which is subdivided into Khondalite Formation, Charnockite Formation and Migmatite formation. The whole rock and mineral dates of the Charnockite, Khondalite and associated granulites of the mobile belt ranges from 3100 to 1000 Ma. The wide range of the dates of granulite facies in the Eastern Ghats may be attributed to resetting of radiometric clock due to several events of igneous intrusions post-dating an earlier episode of granulite facies metamorphism (M2) around 2600/2500 Ma. The Khondalite earlier dated as 3100 Ma also retains the memory of later Pan African event dated between 600 and 450 Ma.

The deformation history of the EGMB is as complicated as its metamorphic evolution, and workers have suggested polyphased deformation and chronologically constrained thermal events in the different parts of Eastern Ghats Group^[2-9]. The geochronological data from different parts of the mobile belt indicate two strong thermal event namely Archaean and Grenvillian^[10-12]. Recently, the presence of several crustal domains in the Eastern Ghats belt has been suggested^[13-18]. These studies are useful for the establishment of the relationship between deformation and metamorphism on local scale, before any generalization is attempted.

Structural Analysis

Nevertheless, review of existing literature on the EGMB shows that there are at least four to five cross-cutting major structural trends aligned in NE-SW, NNE-SSW, NW-SE, N-S and E-W directions. These structural trends are defined by two to three generation of folding events that have given rise tight

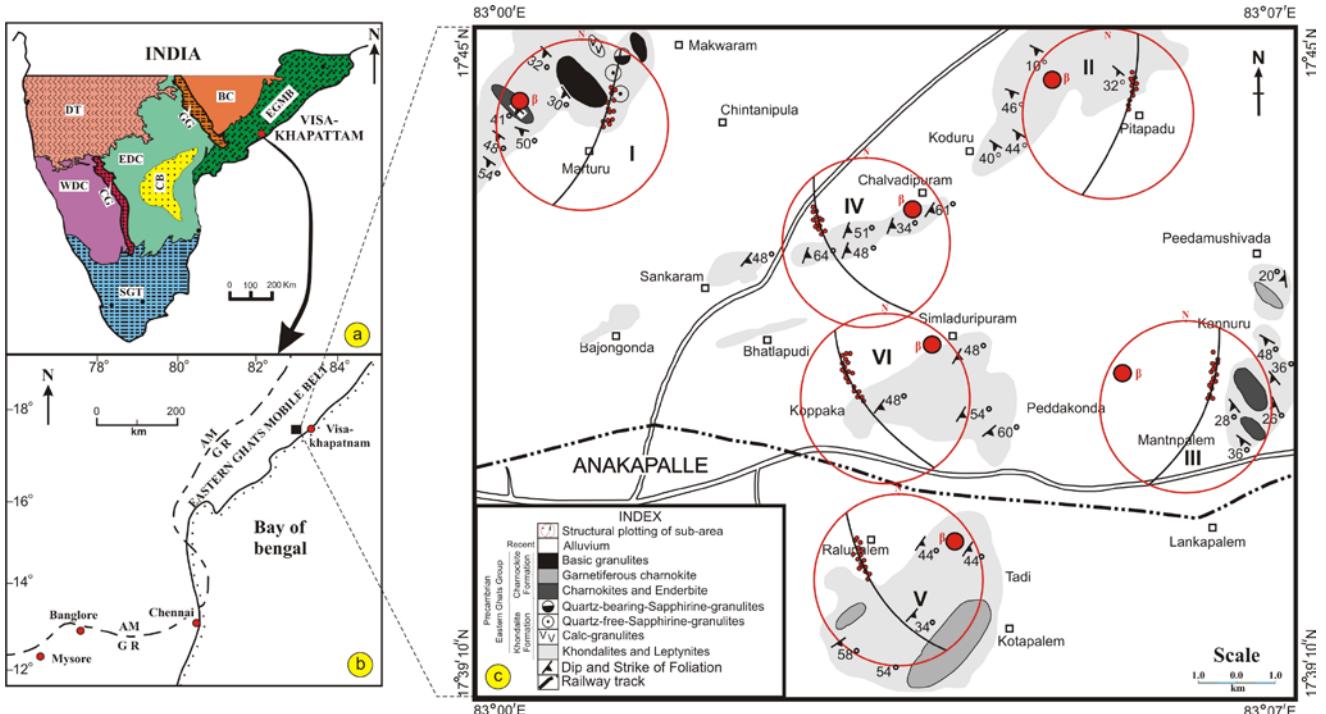


FIG. 1 MAP OF SOUTH INDIA SHOWING THE LITHOLOGIC PATTERNS FOR PRECAMBRIAN ROCKS ALONG WITH CRATON BOUNDARIES. THE ABBREVIATIONS USED ARE: SGT, SOUTHERN GRANULITE TERRAIN; WDC WESTERN DHARWAR CRATON; EDC, EASTERN DHARWAR CRATON; EGMB, EASTERN GHATS MOBILE BELT; BC BASTAR CRATON; DT DECCAN TRAPS; CB CUDDAPAH BASIN; GG, GODAVARI GRABEN. (A) MAP SHOWING THE LOCATION OF THE STUDY AREA (MODIFIED AFTER LAL AND PRAKASH^[28]). (B) GEOLOGICAL MAP WITH STRUCTURAL ANALYSES OF THE STUDY AREA

to open, isoclinal to recumbent and symmetrical to asymmetrical categories of folds. Folds of different generations are variously superimposed and mostly plunging in N, S and W directions^[9, 11, 12].

It appears from earlier work that tectonic history of the EGMB including Vishakhapatnam area is quite complicated and challenging. An attempt has been made in the present work to delineate the tectonic history of area around Anakapalle on the basis of macroscopic structural analysis of planar fabric data and supporting structural and geomorphological field evidences to partly fill the gap of structural information.

The present study area lies in SW of Vishakhapatnam. The country rocks show spectacular fold development and associated metamorphic fabric. For structural analysis, both planer (foliation) and linear (mostly mineral alignment) fabrics have been recorded. However, the most developed planer fabric in the area is the foliation. The two regional foliation trends, one striking NE-SW and dipping to NE and, the other striking in NW-SE and dipping NW have been noticed. The amount of dip of foliation planes varies from 20° to 65°. Among other planer fabrics, closely spaced joints are also present near Kannuru and Tadi village. At these localities fracture cleavages have also been recorded which may be due to presence of closely spaced joints.

Among linear fabrics, mineral lineation defined by parallel arrangement of feldspar grains, elongated quartz crystals, prismatic crystals of sillimanite and elongated garnet in Khondalites are prominently developed in Nasingaraopeta area.

For the purpose of macroscopic structural analysis, the whole study area has been divided into six statistically homogeneous sub-areas based on general orientation of dominant foliation. In each sub-areas, the orientation diagram of poles to S-surfaces was plotted on the lower hemisphere of equal area net. The π -s girdle was drawn in each sub-area and the β -axis (poles to π -s girdle) was determined (Fig. 1c). The π -s diagram in each sub-area was drawn graphically by the method given by Turner and Weiss^[19] and Billings^[20]. After all the poles have been plotted in a sub-area, a best fit girdle is drawn. The pole of the π -s diagram girdle represents the axis along which folding has taken place.

The variation in the trend of β -axis in different sub-areas suggests that the investigated area has undergone repeated folding. Based on orientation of the β -axes in different sub-areas nature of fold patterns have been deduced. The π -s diagram drawn for each domain reveals the amount of plunge and direction of fold axes. Description of each subarea is shown in Fig.1c, and patterns reveal that in subareas I,

II, III folds axes plunge in north-westerly direction ($N60^{\circ}W-N62^{\circ}W$) with the angle of plunge ranging from 18° to 22° . While in subareas IV, V, VI the orientation of β -axis is plunging north-easterly ($N54^{\circ}E-N55^{\circ}E$) with the angle of plunge ranging from 20° to 30° (Fig.1c).



FIG. 2 FIELD PHOTOGRAPH OF HILLOCK OF KHONDALITE SHOWING NORTH EASTERLY PLUNGING FOLD NEAR MARTURU (AVERAGE HEIGHT OF TREES IS APPROXIMATE 20 M)

Macroscopic Geometrical analysis of the folded structure by plotting the $\pi-s$ girdle in different subareas reveals the following facts:

i) The rocks of the area exhibit at least two phases of folding in response to deformation on regional scale.

ii) First phase of deformation D_1 resulted in the F_1 folds with the regional axis in NE-SW direction having average plunge in NW direction at approximate plunge angle of 20° .

iii) Second phase of deformation D_2 has reoriented the axial plane of F_1 fold in NW-SE direction. The F_2 Fold is plunging in NE direction at angles ranging from 20° to 30° .

The above macroscale folds are preserved in the form of residual hills that have been noticed in the areas near Anakapalle and Marturu village. The hill is sloping in north-eastern direction due to plunging of fold (Fig. 2). Some of the folds show two axial planes developed due to shearing (Fig. 3). The Fig.4 shows vertical profile of a part of an isoclinal fold forming a hillock.

Result and discussion

In recent years, structural and geomorphological investigations using remote sensing in conjunction with detailed field collected data analysis has been

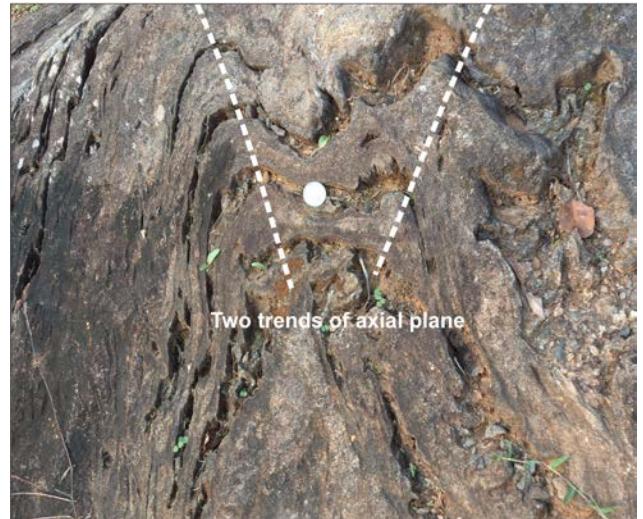


FIG. 3 FIELD PHOTOGRAPH SHOWING TWO TRENDS OF AXIAL PLAINS IN FOLDED BASIC GRANULITES NEAR MAKVARAM (DIAMETER OF THE COIN IS 0.025 M)

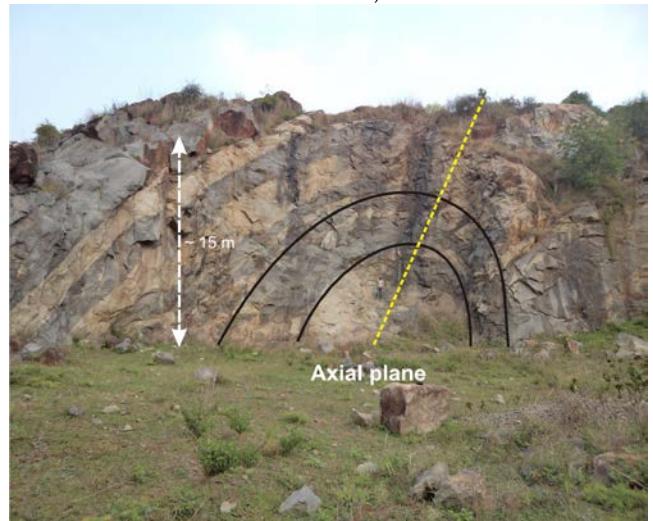


FIG. 4 FIELD PHOTOGRAPH SHOWING VERTICAL SECTION OF PART OF AN ISOCLINAL FOLD IN GRANULITES NEAR MARTURU (HEIGHT OF THE MAN 1.60 M)

attempted by many workers [21, 22, 29]. Therefore, an attempt has been made to correlate our field finding and existing regional trends with the help of remote sensing data. For the purpose, 2, 4 and 5 band combination of LANDSAT 7-ETM+ data, dated 23 Nov. 2006 has been used in the present study. Lineaments trending in NE and NW directions with slight variations at places has been noticed and marked with the broken lines in the Fig.5. In remote sensing data, the broken linear pattern of NE trending plunging ridges is clearly visible due to superimposition of SW trending F_2 folds developed during D_2 deformational phase. These trends are in accord well with the β -axis of plunging folds developed during D_1 and D_2 deformational phases inferred from structural analysis of planer fabric data (Fig. 1). This pattern of deformation characterized with almost 90° rotation of regional fold axis has given rise to exceptionally flat or gently sloping intermontain pediment plains (Fig.5).

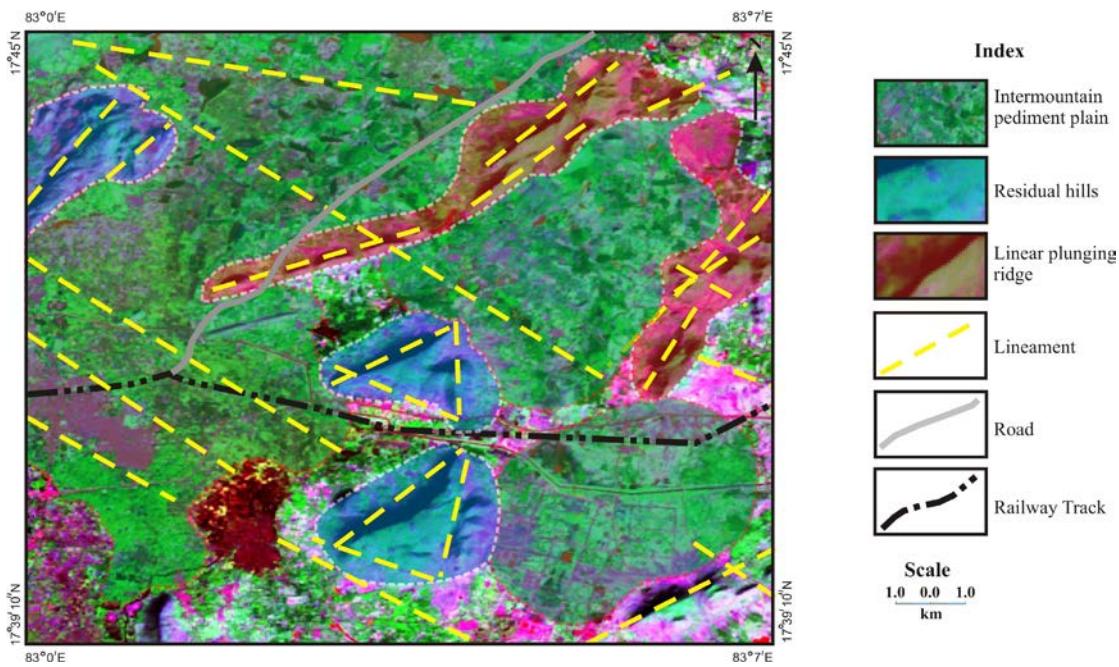


FIG. 5 GEOMORPHOLOGICAL MAP OF THE STUDY AREA TRANSPARENTLY DRAPED OVER LANDSAT 7-ETM+ (REMOTE SENSING DATA DATED 23NOV. 2006)

Therefore, our study integrating field observations with remote sensing data clearly shows that despite multiple phases of folding reported by earlier workers [23–26], the NE-SW and NW-SE structural trends are dominated and seem to have affected the whole of the EGMB area. These two cross-cutting trends have resulted in two prominent phases of folds forming linear ridges, residual hills and pediment plains imparting an uneven topography to the study area. For plunging folds, compressive forces would have been provided by the interacting crustal blocks at different times^[23, 27]. If these events are properly constrained chronologically, structural and metamorphic evolution of the EGMB in particular and cratonic areas of the Peninsular India in general can be better perceived and correlated internationally.

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